Preventive Veterinary Medicine, 4 (1986) 137—158
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

DAIRY CALF MANAGEMENT, MORBIDITY AND MORTALITY IN ONTARIO HOLSTEIN HERDS. III. ASSOCIATION OF MANAGEMENT WITH MORBIDITY

D. WALTNER-TOEWS*, S.W. MARTIN and A.H. MEEK

Department of Veterinary Microbiology and Immunology, University of Guelph, Guelph, Ontario (Canada)

(Accepted for publication 27 March 1986)

ABSTRACT

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986. Dairy calf management, morbidity and mortality in Ontario Holstein herds. III. Association of management with morbidity. *Prev. Vet. Med.*, 4: 137—158.

Associations between heifer calf management and morbidity, particularly scours and pneumonia, were studied on 104 randomly selected Holstein dairy farms in southwestern Ontario between October 1980 and July 1983. At the farm level, data were stratified by season, with two six-month seasons (winter and summer) per year. The odds of farms with particular management strategies having above median morbidity were calculated. At the individual calf level, the odds of a calf being treated, controlling for farm of origin and month of birth, were calculated for different management practices.

Farm size, and policies related to anti-scour vaccination, offering free-choice water and minerals to calves, methods of feeding, and the use of medicated feeds significantly altered the odds of a farm experiencing above-median pneumonia rates. Farm policies with regard to anti-scour vaccination, offering free-choice salt to calves, age at teat removal, type of calf housing, and use of preventive antimicrobials significantly altered the odds of a farm experiencing above-median scours rates.

Scours and pneumonia were significantly associated with each other at both the farm and the calf level. No significant associations were found between individual calf management practices and the odds of being treated for scours. Sire used, method of first colostrum feeding, navel treatment, use of anti-scour vaccine in the dam, and the administration of preventive antimicrobials significantly altered the odds of a calf being treated for pneumonia.

INTRODUCTION

The study of calf morbidity under field conditions raises some serious questions fundamental to the practice of both animal husbandry and veterinary medicine. The most serious and controversial of these questions

*Current address: Yogyakarta Disease Investigation Centre, B.P.P.H. Wil. IV, P.O. Box 79, Yogyakarta, Indonesia.

0167-5877/86/$03.50

concerns the nature of disease itself. Apart from those animals which are moribund or obviously debilitated, when and how do we judge an animal to be sick? Are there objective criteria by which one can judge this?

Some veterinary researchers have attempted to avoid this shady area by evaluating the impact of calf diseases solely on the basis of microbiological laboratory diagnoses (House, 1978). As Murphy (1976) has pointed out, however, any individual will ultimately be declared to be diseased if a sufficient number of laboratory diagnostic tests are performed. In addition, there is no clearly defined association between laboratory test results and true morbidity. Other researchers, such as Hancock (1983), have developed their own scales for measuring the looseness of calf stools in order to give what are essentially qualitative judgements a semblance of objectivity. In many ways this begs the central question: do loose stools reflect disease, and, if so, how, or under what conditions? It is one thing to standardize one's observations; it is another matter entirely to say what the standardized observations mean.

The most obvious measure of morbidity — farmer diagnosed and treated disease — appears on the face of it to be an unreliable measure of disease. Nevertheless, it can be argued that calf diseases measured in this way reflect the clinical syndromes of interest to dairy farmers, and deserves study if only for that reason. The ability of a farmer to recognize clinical signs, his willingness to treat, and his record-keeping habits all contribute to whether or not calves are recorded as having been treated on a particular farm. Some, but not all, of these difficulties can be overcome by standardizing and monitoring record-keeping practices, and by using large numbers of farms. Also, since these factors are likely to be consistent within farms, farm-level management effects can be assessed by looking for consonant patterns at the individual animal level on a within-farm basis. For instance, if farms which usually house calves in hutches have, in general, lower rates of treatments for scours, then calves housed in hutches on farms with more than one housing system should be less likely to be treated for scours than their herd-mates. Consistency between farm-level and individual animal-level findings lends strength to a hypothesis of causality (Susser, 1973).

The objectives of this observational study were to assess the impact of dairy calf management policies on rates of disease treatment by farmers, and to assess the impact of individual calf management factors on individual calf morbidity. Analyses were carried out with all diagnoses combined, and two sub-classes of clinical diagnosis — pneumonia and scours — as endpoints. In this study, the terms "crude morbidity" and "all diagnoses" are used interchangeably to refer to a pooled morbidity category, which includes all calves treated therapeutically for whatever reason.

MATERIALS AND METHODS

Study population

Farm-level calf management and outcome data were collected from an initial random sample of 110 Holstein dairy farms in southwestern Ontario, over a period of about two and one-half years. Individual heifer calf data were collected on a subsample of 35 of these farms. The method of selection of these farms and a description of calf management and outcomes were presented earlier (Waltner-Toews et al., 1986a). All analyses were carried out based on heifer calf data only. For analytical purposes, the neonatal period was defined as the period from birth up to and including 28 days of age. The pre-weaning period covered the entire time from birth until calves were no longer fed milk or milk substitutes on a regular basis. This latter time period varied from farm to farm.

Management variables

Records were kept on all farms on standardized forms. Record-keeping habits were monitored and scored as poor, fair and good by technicians who regularly visited the farms. Farm calf management data were derived from interview questionnaires and farm visits; details of individual calf management were based on specially designed calf birthday forms. Preventive treatments, at both the farm and the individual calf level, were those given to a dam within six weeks before calving, or to the newborn calf in the absence of recognizable disease.

Outcome variables

At the farm level, morbidity rates were estimated by treatment days per calf during a given 'season'; winter was the period 16 November—15 May and summer was the period 16 May—15 November. The rates were calculated as (number of calf treatment days) ÷ (number of live-born calves) during each time period. Losses due to death or sale were small and were not accounted for in these analyses. For analytical purposes, farms were classified as being above or below the median treatment days per calf for a given season.

On the subset of farms where individual calf information was kept, measuring tapes (Coburn weight-by-breed dairy cow tape, the Coburn Co., Inc., Whitewater, WI 53190, USA) were provided part-way through the study, and farmers were instructed how to take heart-girth measurements. These measurements were to be taken on calves at birth, two weeks of age, and at weaning.

Statistical analyses

Since farms were classified as being above or below the median value for treatment days per calf, the effects of management on all diagnoses combined, and on pneumonia and scours in particular, were assessed using multiple stepwise logistic regression (Breslow and Day, 1980; Dixon, 1983). The county in which the farm was located (COUNTY), year (YEAR), record-keeping score (REC) and usual weaning age per farm (WEAN) were included in all models. Some variables, such as those concerned with whether or not hutches were moved between calves, or whether or not indoor calf pens were in an air space separate from the adult cows, only applied to particular subsets of farms. These were analyzed by means of two-way tables, stratified by year, with differences tested by chi-square or Fisher's Exact test.

At the individual calf level, whether or not calves were treated (all diagnoses), or treated specifically for pneumonia or for scours were analyzed using multiple stepwise logistic regression. Farm, and time of birth (month and year) were included in all models.

Initially, variables were allowed to enter the logistic models if they explained a significant portion of the residual variation, based on an estimated F, and a p-value to enter at $\leqslant 0.10$. If a variable, once in the model, was found not to contribute significantly to the model, controlling for other variables in the model, it was removed, based on an estimated F, and a p-value to remove at $\leqslant 0.15$. In order to determine whether or not some factors in the model might significantly alter the effects of other factors, also in the model, (for instance, assisted colostrum feeding in calves that required birthing assistance, versus feeding assistance in naturally-born calves), models including interaction terms were constructed. Only biologically plausible interactions of those variables which had entered the main effects models were considered for entry. In these analyses, the p-values for F-to-enter and F-to-remove were set at $\leqslant 0.05$ and $\leqslant 0.10$, respectively, with all terms (main effects and interactions) being offered for entry. The adequacy of the logistic model for the data was assessed using Brown's statistic, and the fit of the specific model to the data was evaluated based on Lemeshow and Hosmer's statistic (Lemeshow and Hosmer, 1982; Dixon, 1983). Variables and associations reported in the tables are those included in the interaction models.

Factors which apparently influenced age at first treatment, duration of treatment and weight gains were analyzed using multiple linear least squares regression (Draper and Smith, 1981; SAS, 1982; Dixon, 1983). In the first step, all possible subsets regressions were run. The 'best' model was selected based on the lowest value for Mallow's Cp statistic. This model was then more fully evaluated by examination of residuals and normal probability plots. A dummy variable for each farm was included in all models. Time of birth (season) was included as a binary variable (WINTER). This was coded as one if the calf was born between 16 November and 15 May, and zero otherwise, and was available for entry, but was not forced in. Other variables, such as EASE, were also recoded into the binary form (CALVE-ASSIST) for the multiple linear regression analysis. Variables with coefficients in the 'best' subset model which were not significant at $P \leqslant 0.05$ were then excluded, and the model re-run.

At the farm level, 30 different management variables (apart from REC, COUNTY, YEAR and WEAN) could be evaluated using the complete set of farms. These variables covered a wide range of aspects of calving and calf management (Table I). At the individual calf level, 15 management variables (other than farm effect and month and year of birth) were evaluated in about 1800 calves (Table I).

On different subsets of calves, the effects of estimated birthweight (from heart-girth measurements) (n=614), calf housing and age at removal from dam (n=682) could also be evaluated.

RESULTS

Outcome variables

As reported earlier (Waltner-Toews et al., 1986a), 20.5% of 1968 heifer calves were treated for scours, and 15.4% were treated for pneumonia on the study farms. Case fatality rates for pneumonia, scours, a combination thereof, or other diseases, did not differ significantly from each other, and ranged from 5.5% (pneumonia) to 7.1% (diseases other than scours and pneumonia). Of 1280 calves which were not seen to be sick, 2.3% died. This was significantly lower (χ^2=20.3, $P \leqslant 0.0001$) than the case fatality rate in the pooled disease categories.

The risk of pneumonia in individual calves was significantly increased by a factor (odds ratio) of three if they also had scours during the same time period (Table II). Treatment for scours did not always precede treatment for pneumonia. However, since the risk of scours treatment peaked earlier in the life of these calves (at about 10 days) than the risk of pneumonia treatment (at about six weeks), scours is presented as if it were an antecedent variable.

The median farm treatment days per calf are displayed in Table III. The median number of treatment days per calf for scours was zero for every season. Hence these analyses differentiated between farms with no treatments for scours and those with any treatment for scours. The median number of treatment days per calf for pneumonia, and for all diagnoses combined, varied from season to season.

At the farm level, the association between scours and pneumonia for both summer and winter seasons was consistent with what was seen at the individual calf level. Using the method of Mantel and Haenszel (1959) to summarize across years, the winter odds ratio was 2.2 (χ^2=9.4; $P \leqslant 0.005$)

TABLE I

Description of husbandry variables used in the study of relationships between management, morbidity and mortality in dairy calves in southwestern Ontario, 1980—83

BIRTHPLACE[a,b]	Place where calf was born
EASE[a]	Ease of calving
CALVE-ASSIST[b]	Calves routinely pulled or not
TIME[a]	Time of birth. Day = 6 AM to 10 PM
NAVEL-TREAT[a,b]	Was calf's navel treated at birth
WHEN-COLOSTRUM[a,b]	Time post-partum first colostrum offered
HOW-COLOSTRUM[a,b]	How first colostrum offered to calf
CALF-ANTIMICROBIAL[a,b]	Antimicrobials given healthy newborn calf
CALF-VITAMIN[a,b]	Vitamins given healthy newborn calf
CALF-SE[a,b]	Selenium given healthy newborn calf
CALF-VACCINATION[a,b]	Scour vaccination given healthy newborn calf
COW-ADE[a,b]	Prev. vit. ADE to dam $\leqslant$ 6 wks prepartum
COW-D[a]	Prev. vit. D to dam $\leqslant$ 6 wks prepartum
COW-SE[a,b]	Prev. selenium to dam $\leqslant$ 6 wks prepartum
COW-VACCINATION[a,b]	Scour vaccination to dam $\leqslant$ 6 wks prepartum
SIRE[a]	Sire of calf
CALF-HOUSING[a,b]	Type of housing for calves to weaning
REMOVAL-AGE[a,b]	Age in days when calf removed from dam
BIRTHWEIGHT[a]	Estimated from heart-girth measurement
TEAT-REMOVAL[b]	If teats removed preweaning, at what age
HORN-REMOVAL[b]	If horns removed preweaning, at what age
TYPE-OF-FEED[b]	Liquid calf feed (milk, milk replacer, etc)
VOLUME-PER-FEED[b]	Volume of liquid feed fed to calves
ANTIMICROBIALS-FEED[b]	Antimicrobials in starter or replacer
PAIL-FEEDING START[b]	Age at which pail feeding started
SALT-OFFERED[b]	Age salt first offered to calves
MINERAL-OFFERED[b]	Age mineral first offered to calves
WATER-OFFERED[b]	Age fresh water first offered to calves
HAY-OFFERED[b]	Age hay first offered to calves
STARTER-OFFERED[b]	Age starter first offered to calves
CALFSTART[b]	Type of calf starter (commercial, home-mix, etc.)
OBSERVED CALVINGS[b]	Proportion of calvings attended
FARM SIZE[b]	No. of calvings resulting in a lactation/year
BULLS[b]	Age to which bull calves reared
CALF-CARE[b]	Person(s) responsible for calf care

[a] Assessed at individual calf level.
[b] Assessed at farm level as a general policy.

and the summer odds ratio was 3.0 (χ^2=12.2; $P \leqslant 0.0005$). That is, farms that had above the median number of treatment days for scours (or, in other words, which experienced at least one episode of calf scours) had a two to three times increase in risk of having above-median treatment days per calf for pneumonia.

Also, farms with above the median treatment days per calf for pneumonia were 2.3 times more likely to have above-median mortality rates

TABLE II

The association between pneumonia and scours in individual heifer calves on Holstein dairy farms in southwestern Ontario, 1980—83

		Pneumonia		
		Treated	Not treated	Percent treated
Scours	Treated	116	287	28.8
	Not Treated	186	1379	11.9

χ^2=70.452, P=0.0001; odds ratio = 3.0.

TABLE III

Median treatment days per calf for heifer calves on Holstein dairy farms in southwestern Ontario, 1981—83, by season[a]

Season	Number of farms	All diagnoses	Scours	Pneumonia
Winter 1	103	0.94	0.00	0.20
Summer 1	104	0.50	0.00	0.00
Winter 2	103	0.78	0.00	0.30
Summer 2	97	0.57	0.00	0.00
Winter 3	87	0.57	0.00	0.00

[a]See text for definition of seasons. Treatment rates were calculated as (number of calf treatment days) ÷ (number of live-born calves), for each clinical endpoint, for each farm, for each season.

than farms with below the median treatment days per calf. For scours treatment, the odds ratio was 1.9 for its association with mortality. For both scours and pneumonia treatment days per calf, the association with mortality was strongest during the summer months.

Farm-level calf management policies included in the final logistic regression models as predictors of disease in general (all diagnoses), and for pneumonia and scours are displayed in Tables IV to VI. Among those variables which only applied to some of the farms and which were analyzed by the chi-square or Fisher's Exact tests, none was significantly associated with whether or not farms experienced above-median treatment days. Individual calf management factors associated with all diseases, and with pneumonia, are displayed in Tables VII and VIII.

In Tables IV to VIII, only those odds ratios whose 95% confidence interval (CI) did not include 1 are displayed. The logistic regression coefficients and their standard errors can be calculated from the adjusted odds ratios and either one of the confidence limits (CL). For instance, the odds ratio and 95% CL for COW-VACCINATION in Table IV are 5.47 and 2.01, 14.85. The logistic regression coefficient is the natural log (ln) of 5.47, that is, 1.699. The standard error, calculated from the lower confidence limit, is $(1.699 - \ln(2.01)) \div 1.96 = 0.51$.

For variables, or levels of variables, which were not significant at $P \leqslant 0.05$, but were included in the final model, only the direction of the effect is shown. A positive sign indicates an odds ratio of > 1, and a negative sign indicates an odds ratio of < 1. Lemeshow and Hosmer's statistics for the final models indicated an adequate fit to the data for all the logistic models except that for neonatal pneumonia (Table IX).

No individual calf management factors were significantly associated with whether or not a calf was treated for scours neonatally (≤ 28 days) or during the pre-weaning period. Only COW-VACCINATION significantly

TABLE IV

Heifer calf management policies affecting whether or not Holstein dairy farms in south-western Ontario experienced above-median treatment days per calf (all diagnoses), 1981—83

Variable	Categories	OR[a] (95% CL)
A. *Winter season: 16 November—15 May*		
COW-VACCINATION	Vs no vaccine program	5.47 (2.01, 14.85)
B. *Summer season: 16 May—15 November*		
TEAT-REMOVAL	≤ 4 wks vs not removed	+
	> 4 wks vs not removed	137.79 (10.8, 1754.22)
VOLUME-PER-FEED	≥ 1 qt vs < 1 qt	+
TYPE-OF-FEED	Waste milk vs whole milk	19.60 (1.04, 367.95)
	Replacer vs whole milk	6.59 (2.00, 21.67)
	Colostrum[b] vs whole milk	-
	Other vs whole milk	4.70 (1.01, 22.06)
CALF-HOUSING	Group vs individual pens	+
	Hutches vs individual pens	0.29 (0.09, 0.96)
	Other vs individual pens	+
WHEN-COLOSTRUM	≥ 2 h vs < 2 h	0.25 (0.10, 0.64)
PAIL-FEEDING START	< 2 wks vs not used	0.16 (0.04, 0.69)
	> 2 wks vs not used	0.15 (0.03, 0.81)
ANTIMICROBIALS-FEED	Vs none	0.33 (0.11, 0.99)

[a]Odds ratio of having above-median treatment days (see Table III), controlling for county, year, record-keeping score and weaning age. Figures are only given for odds ratios significant at $P \leqslant 0.05$. For other variables, or levels of variables, a '+' indicates a mean odds ratio of > 1, and a '-' indicates an odds ratio of < 1.
[b]Sour or preserved colostrum.

increased the odds of being treated for pneumonia during the neonatal period (odds ratio 2.98; 95% CL 1.11, 3.29).

The effect of SIRE for each of the 16 selected bulls was calculated with all other sires as the base-line category. In this study, the SIRE effect was significant only for pre-weaning pneumonia. The overall effect was primarily driven by a few bulls whose calves experienced higher treatment rates for pneumonia than the calves from other bulls.

When only those calves were considered for which REMOVAL-AGE and CALF-HOUSING details were available (n=682), CALF-HOUSING appeared as the first significant factor in the logistic regression models for all diagnoses, for pneumonia, and for scours. In each case, this was because calves raised in outdoor hutches were much less likely to be treated than calves raised in inside individual pens, the latter being the baseline category. Mean odds ratios varied from 0.04 for hutches versus individual pens in the pneumonia model to 0.12 for hutches versus individual pens in the scour model. In other words, calves raised in hutches were 25 times less likely to be treated for pneumonia, and 8 times less likely to be treated for scours, than calves raised inside, in individual pens. Calves raised in other forms of housing,

TABLE V

Heifer calf management policies affecting whether or not Holstein dairy farms in southwestern Ontario experienced above-median treatment days per calf for pneumonia, 1981—83

Variable	Categories	OR[a] (95% CL)
A. *Winter season: 16 November—15 May*		
COW-VACCINATION	Vs no vaccine program	4.64 (1.52, 14.11)
ANTIMICROBIALS-FEED	Vs none	0.40 (0.19, 0.81)
WATER-OFFERED	≤ 2 wks vs not offered	-
	> 2 wks vs not offered	0.24 (0.11, 0.51)
PAIL-FEEDING START	≤ 2 wks vs not used	-
	> 2 wks vs not used	0.24 (0.04, 0.48)
FARM SIZE		1.02[b] (1.01, 10.3)
MINERAL-OFFERED	≤ 2 wks vs not offered	5.35 (1.15, 24.84)
	> 2 wks vs not offered	+
B. *Summer season: 16 May—15 November*		
FARM SIZE		1.01[b] (1.01, 1.03)

[a]Odds ratio of having above median treatment days (see Table III), controlling for county, year, record-keeping score and weaning age. Figures are only given for odds ratios significant at $P \leq 0.05$. For other variables, or levels of variables, a '+' indicates a mean odds ratio of > 1, and a '–' indicates an odds ratio of < 1.
[b]Odds ratio for farms that differ by one calving per year.

TABLE VI

Heifer calf management policies affecting whether or not Holstein dairy farms in southwestern Ontario experienced at least one episode of scours, 1981—83

Variable	Categories	OR[a] (95%)
A. *Winter season: 16 November—15 May*		
COW-VACCINATION	Vs no vaccine program	4.71 (1.66, 13.41)
SALT-OFFERED	≤ 2 wks vs not offered	-
	> 2 wks vs not offered	0.22 (0.08, 0.59)
CALF-HOUSING	Grp. pens vs ind. pens	+
	Hutches vs ind. pens	0.22 (0.08, 0.62)
	Other vs ind. pens	-
TEAT-REMOVAL	≤ 4 wks vs not removed	+
	> 4 wks vs not removed	4.96 (1.50, 16.46)
B. *Summer season: 16 May—15 November*		
CALF-ANTIMICROBIAL	Vs not routinely given	2.53 (1.12, 5.69)

[a]Odds ratio of having above-median treatment days (zero), controlling for county, year, record-keeping score and weaning age. Figures are only given for odds ratios significant at $P \leq 0.05$. For other variables, or levels of variables, a '+' indicates a mean odds ratio of > 1, and a '-' indicates an odds ratio of < 1.

TABLE VII

Individual heifer calf management factors affecting whether or not calves were treated (all diagnoses) on Holstein dairy farms in southwestern Ontario, 1980—83

Variable	Categories	OR[a] (95% CL)
COW-D	Vs no vitamin D given	0.31 (0.12, 0.77)
TIME	Day vs night	0.76 (0.59, 0.96)
HOW-COLOSTRUM	Assisted vs suckled[b]	1.61 (1.04, 2.48)
	Drench vs suckled	+
	Nipple feeder vs suckled	-
	Pail vs suckled	2.42 (1.18, 4.98)
	Other vs suckle only	-

[a]Odds ratio of being treated for disease controlling for farm, month and year of birth. Figures are only given for odds ratios significant at $P \leq 0.05$. For other variables, or levels of variables, a '+' indicates a mean odds ratio of > 1, and a '-' indicates an odds ratio of < 1.
[b]Calves in the suckled category received no assistance or supplementation for first colostrum feeding.

TABLE VIII

Individual heifer calf management factors affecting whether or not calves were treated for pneumonia on Holstein dairy farms in southwestern Ontario, 1980—83

Variable	Explanation	OR[a] (95% CL)
HOW-COLOSTRUM	Assisted vs suckled[b]	3.31 (1.20, 9.14)
	Drench vs suckled	-
	Nipple feeder vs suckled	-
	Pail vs suckled	-
	Other vs suckled	+
TIME	Day vs night	-
HOW-COLOSTRUM × TIME	Assisted × day	-
	Drench × day	+
	Nipple × day	-
	Pail × day	19.15 (1.79, 212.79)
	Other × day	-
NAVEL-TREAT	Iodine vs no navel tx.	-
	Chlorhexidine vs no tx.	-
	Other vs no navel tx.	2.94 (1.32, 6.55)
SIRE[c]	Various	
COW-VACCINATION	Vs none given	2.21 (1.03, 4.75)
CALF-ANTIMICROBIAL	Vs none given preventively	0.46 (0.21, 0.99)

[a]Odds ratio of being treated for pneumonia, controlling for farm, month and year of birth. Figures are only given for odds ratios significant at $P \leqslant 0.05$. For other variables, or levels of variables, a '+' indicates a mean odds ratio of > 1, and a '-' indicates an odds ratio of < 1.
[b]Calves in the suckled category received no assistance or supplementation for first colostrum feeding.
[c]See text for explanation.

including group pens, did not differ significantly in outcome from those raised inside in individual pens. In the crude morbidity (all diagnoses combined) model, calves left with the dam longer tended to be less likely to be treated ($P \leqslant 0.10$) than calves removed at one day of age.

When only those calves for which a heart-girth measurement at birth was available (n=614) were considered, estimated BIRTHWEIGHT did not significantly affect any of the outcomes.

Individual calf management factors included in the best subset model for age of onset and duration of disease are displayed in Tables X and XI. After controlling for the farm effect, only the season of birth added significantly to the model predicting two-week weight gains. Calves born in winter had lower rates of gain (coefficient = 0.285, P = 0.017) than calves born during the summer. Pasture-born calves tended ($P \leqslant 0.08$) to have a higher rate of gain than calves born elsewhere. When farm effect was controlled, none of

TABLE IX

Lemeshow and Hosmer's chi-square goodness-of-fit statistic for final logistic models of factors affecting various forms of morbidity on Holstein dairy farms in southwestern Ontario, 1980—83

Level of analysis	Model	p-value of statistic[a]
Farm-winter	All diagnoses	0.609
	Pneumonia	0.823
	Scours	0.726
Farm-summer	All diagnoses	0.462
	Pneumonia	0.567
	Scours	0.252
Individual-neonatal	All diagnoses	No model
	Pneumonia	0.016
	Scours	No model
Individual-pre-weaning	All diagnoses	0.273
	Pneumonia	0.668
	Scours	No model

[a] A large p-value indicates a good fit to the data.

TABLE X

Individual heifer calf management factors affecting age of first treatment and duration of treatments for crude morbidity on Holstein dairy farms in southwestern Ontario, 1980—83

Variable	Explanation	Coeff.[a] (p-value)
Age of first treatment		
WINTER[b]	Vs summer	-0.239 (0.002)
CALVE-ASSIST	Vs no assistance at calving	-0.201 (0.006)
CALF-ANTIMICROBIAL	Vs none given preventively	-0.819 (0.029)
CALF-VACCINATION	Vs none given	-0.511 (0.004)
Duration of treatment		
COW-D	Vs no vit. D given	-0.575 (0.035)
CALF-VACCINATION	Vs none given	-0.631 (0.039)
NAVEL-IODINE	Vs no iodine on navel	+0.310 (0.020)

[a] These are unstandardized regression coefficients. The p-value given is for the partial t-test of the coefficient. All independent variables considered were binary. The models include a dummy variable for each farm. Coefficients are relative to the natural logarithm of the endpoint.
[b] See text for explanation.

TABLE XI

Individual heifer calf management factors within farms affecting age of first treatment and duration of treatment for scours and pneumonia on Holstein dairy farms in south-western Ontario, 1980–83

Dependent variable	Predictor variable	Coeff.[a] (p-value)
Age: pneumonia	WINTER[b]	
	vs summer	-0.387 (0.001)
Age: scours	CALF-VACCINATION	
	vs none given	-0.915 (0.005)
Duration: pneumonia	PASTURE-BIRTH	
	vs nonpasture birth	-0.464 (0.001)
Duration: scours	COW-VACCINATION	
	vs none given	+0.253 (0.014)
	COW-ADE	
	vs no vit. ADE given	+0.230 (0.015)

[a]These are unstandardized regression coefficients. The p-value given is for the t-test of the coefficient. All independent variables considered were binary. The models include a dummy variable for each farm. Coefficients are relative to the natural logarithm of the endpoint.
[b]See text for explanation.

TABLE XII

Values of R^2 for final multiple regression models of age of first treatment, duration of treatment, and weight gains in heifer calves on Holstein dairy farms in southwestern Ontario, 1981–83

Model	R^2	F-statistic
Age of first sickness	0.259	5.93 (38, 644)[a]
Duration of sickness	0.418	12.11 (37, 625)
Age of first pneumonia	0.212	2.18 (33, 267)
Duration of pneumonia	0.468	7.15 (33, 268)
Age of first scours	0.191	2.82 (31, 371)
Duration of scours	0.497	10.92 (32, 354)
Two-week weight gain	0.654	13.55 (18, 129)

[a]Numbers in parentheses are numerator and denominator degrees of freedom, respectively. All models were significant at $P < 0.001$.

the variables measured added significantly to the weight-gains to weaning model.

The models selected were able to explain 20–25% of the variation in age at first treatment, 40–50% in duration of treatment, and 65% in estimated two-week weight gains (Table XII). On the basis of residual analysis, the multiple regression models were deemed to be adequate for the analyses of these data.

DISCUSSION

Associations between pneumonia, scours and mortality

The association of above-median treatment days for scours with above-median treatment days for pneumonia, at the farm level, suggests that at least some common factors pre-dispose to both syndromes, whether they be management techniques or specific agents. At the individual animal level, of the 116 calves which succumbed to both scours and pneumonia, 74 (63.8%) were treated for scours before pneumonia and 26 (22.4%) simultaneously for scours and pneumonia. Similar associations were found by Willeberg et al. (1978) in pigs, where scours preceded pneumonia 61% of the time. This raises the possibility that, besides common agents or husbandry predisposing to both diseases, a more general pathophysiological mechanism may be at work in which animals with diarrhea (or at least, which are treated for diarrhea) succumb, at a later date, to pneumonia. On the other hand, it may simply be that once a calf has been treated for diarrhea, clinicians and farmers watch that calf more closely, and treat it more readily, than they do other calves.

The significantly lower mortality rate in calves not seen to be sick indicates that, whatever the various treatments for disease were, they were not sufficiently effective to bring the case fatality rate down to what might be viewed as baseline or background mortality. Indeed, this could be expected, since no known treatments are 100% effective in curing calf diseases.

The positive association between disease and mortality at an individual calf level is consistent with the similar association seen at farm level.

Estimated weight gains as an outcome

It was suggested in an earlier paper (Waltner-Toews et al., 1986a) that the heart-girth measurements taken in this study might be too variable to assess anything but the most crude variations in weights and weight gains, except if carried out under frequent, periodic supervision. Thus it is not surprising that, once the farm effect was controlled, only season (and perhaps pasture birth) added to the model. Similarly, the fact that no variables loaded significantly into the model for predicting pre-weaning weight gains, and the lack of effect of estimated BIRTHWEIGHT on morbidity, may simply reflect the lack of accuracy of the measuring instrument.

Associations of morbidity with farm size and season

The small positive odds ratio associated with increasing FARM SIZE and pneumonia treatment days per calf (Table V) reflects the fact that it is measuring the difference in odds seen between farms that differ in size by only one calving per year. If one were measuring the odds of an 80-calvings-per-year farm having above-median pneumonia treatment rates versus a 20-calvings-per-year farm, the logarithm of the odds ratio would increase by a factor of 60, and the odds ratio itself would be 3.3.

The finding that calves were treated sooner (crude morbidity, pneumonia) and longer (crude morbidity) during the winter months than during the summer (Tables IX and X) is consistent with other seasonal patterns seen in this study population (Waltner-Toews et al., 1986b). The lower winter weight gains also fit into this pattern.

Associations of morbidity with preventive treatments

Very few active preventive treatments could be used to differentiate high morbidity from low morbidity farms. However, if farm-level and calf-level associations are evaluated in an integrated fashion, a number of patterns emerge.

Most of the anti-scour vaccines (75.5%) given to dams in the last six weeks of pregnancy were administered as part of a vaccine field trial. The possible detrimental effect of this vaccine is discussed more fully in that context (Waltner-Toews et al., 1985), and will not be pursued at length here. This study nevertheless extends the vaccine trial findings in suggesting that, at the farm level, COW-VACCINATION was associated with increased winter morbidity in general (all diagnoses), as well as for scours and pneumonia in particular (Tables IV to VI). Within vaccinating farms, calves from vaccinated dams were more likely to be treated for pneumonia during the neonatal period than calves from non-vaccinated dams. Within farms, calves from vaccinated dams were treated longer for scours than calves from non-vaccinated dams.

The association of COW-VACCINATION with pneumonia at the individual calf level may indicate that vaccination of the pregnant cow exerts a subclinical stress on the fetal immune system, the results of which are expressed in the post-natal period. At the farm level, this association may represent something more complex, which includes an expectation of disease, and/or increased vigilance and increased treatment rates, on the part of the farmer, perhaps superimposed on a basic biological phenomenon.

There was a tendency for farms which routinely vaccinated newborn calves against scours (CALF-VACCINATION) to have above median scours treatment days per calf (summer and winter, $P \leqslant 0.10$; data not shown). Within those farms that did vaccinate some of their newborn calves, vaccinated calves were treated at a younger age (crude morbidity, scours) and for a shorter time (crude morbidity) than non-vaccinated calves. (Tables X and XI). None of these calf vaccines was given randomly, for instance as part of a field trial. Hence, this may reflect either a stress effect from the vaccination or simply increased vigilance on the part of the farmers against disease in the calves which they had vaccinated. This would have led to earlier treatment, and perhaps treatment of milder disorders, than in calves not so carefully watched. These farm-level trends may indicate that farmers with scours problems in their calves attempted to remedy the situation through calf vaccination.

The use of medicated calf starter or milk replacer (ANTIMOCROBIALS-FEED) was associated with decreased odds of having above-median treatment days per calf in general (crude morbidity) and for pneumonia. The actual administration of antimicrobials to newborn calves (CALF-ANTIMICROBIAL) produced variable results, being associated with increased odds of having summer scours at the farm level (Table VI) and decreased odds of being treated for pneumonia at the individual animal level (Table VIII). These findings are discussed more fully elsewhere (Waltner-Toews et al., 1986d), but suggest that the preventive use of antimicrobials in dairy calves should be re-assessed using formal field trials.

Other preventive treatments evaluated were the administration of vitamins or selenium to pregnant dams or newborn calves (farm and individual level) and the administration of vitamin D (a preventive for milk fever) to pregnant dams (individual level only). Policies of giving vitamin or selenium injections to pregnant dams or newborn calves had no discernible effect on morbidity in heifer calves on these farms.

At the individual calf level, the longer duration of scours in calves from vitamin ADE-treated dams (COW-ADE) (Table XI) may reflect, at least in part, a seasonal effect, since more dams were injected in winter than in summer. In the subsets of calves in which housing was evaluated, the administration of selenium to pregnant dams tended to be associated with increased odds of being treated (scours, crude morbidity, $P \leqslant 0.10$), whereas giving selenium to newborn calves tended to decrease these odds (scours, crude morbidity $P \leqslant 0.10$). In the full data set, calves from selenium-treated dams had a tendency ($P \leqslant 0.09$) to be less likely to be treated for neonatal pneumonia ($\leqslant$ 28 days) than other calves (data not shown). Another study carried out on these farms measured the selenium content of the hair of newborn calves, and related this to subsequent morbidity (Waltner-Toews et al., 1986e). The latter study found a tendency toward lower rates of neonatal morbidity among calves with higher selenium status. These two studies, then, would tend to support the practice of administering selenium to newborn calves.

The association of vitamin D administration to pregnant dams with decreased odds of treatment and shorter treatments (crude morbidity) is probably more related to the age of the dam than it is to some direct biological mechanism, although the latter cannot be ruled out. No clear relationship appeared, in this study, between calving ease and vitamin D administration. However, older cows would have been more likely to receive the preventive treatment. These same cows may have produced colostrum with antibodies against a wider array of antigens which, in turn, would have had an effect on calf morbidity (Bradley et al., 1979; Roy, 1980b).

Navel treatment of newborn calves, while still recommended in the popular press (Heider, 1980), has never been demonstrated to have a significant beneficial effect on calf morbidity or mortality. In this study, a policy of routine navel treatments had no significant effect on morbidity rates. At the individual calf level, navel treatment was either harmful (prolonged treatments if iodine was used; greater odds of being treated for pneumonia if anything other than iodine or chlorhexidine was used), or had no significant effect. Chlorhexidine and iodine had no significant effect in the pneumonia model (Table VIII). This evidence calls into question any continued recommendation of navel treatments in general terms; of the various substances used to treat navels on these farms, only chlorhexidine appears to have had either no effect (on morbidity) or a sparing effect (on mortality; cf. Waltner-Toews et al., 1986c) and hence can be recommended.

Associations of morbidity with calving factors

At the individual calf level, the lowered odds of treatment for pneumonia and crude morbidity for day-born calves (Tables VII and VIII) is probably related to better calving management during the day. Similarly, the observation that calves requiring assistance at birth were treated sooner than calves not requiring assistance (Table X) may reflect either a true biological effect, or simply increased concern and vigilance on the part of the farmer.

Calving ease and perinatal calf mortality have both been reported to have genetic components attributable to the sire. This study suggests that calf morbidity, particularly pneumonia, may have a genetic component as well (Table VIII, SIRE effect). According to Spooner et al. (1975), such an effect would be biologically plausible. Long-term follow-up on morbidity in calves from various sires in a large population data-base, such as that available to artificial insemination organizations, would be helpful in clarifying these effects and determining if, indeed, they are heritable to any significant degree.

Associations of morbidity with colostrum feeding practices

Under experimental conditions the timing and method of feeding of first colostrum have been demonstrated to significantly affect serum immunoglobulin levels in calves. Colostral IgG content has been reported to decrease sharply between 2 and 12 h post-partum (Hoerlein and Jones, 1977). Closure of the calf's intestine to absorption of immunoglobulins begins soon after birth, and increases rapidly after 12 h (Selman, 1973; Stott et al., 1979). Suckled calves have been shown to absorb immunoglobulins more efficiently than calves removed from their dams and hand-fed (Selman et al., 1971b; Stott et al., 1979). This has been related to the presence of the dam per se (Selman et al., 1971b; Selman, 1973) and/or to a specific suckling effect (Fallon, 1979; Stott et al., 1979). Finally, low calf serum immunoglobulin levels have been related to both higher morbidity and mortality by a number of authors (Hurvell and Fey, 1970; Selman et al., 1971a; Boyd, 1972; Irwin, 1974; Fallon, 1979).

Given the strong experimental evidence for the importance of timing of first colostrum feeding, the results of this study are somewhat surprising. In this study, the variable WHEN-COLOSTRUM was based on when the farmer thought (by observation or inference) the calves first received their colostrum. In an earlier paper (Waltner-Toews et al., 1986a), farm policies of delayed or early colostrum feeding on these farms were demonstrated to bear no significant relationship to what actually occurred at the individual calf level. Hence the inclusion of WHEN-COLOSTRUM as a significant variable in the farm-level summer morbidity model (Table IV) indicates that this variable is probably a surrogate measure for some other factor not measured in this study.

Although 'usual' methods of first colostrum feeding had no significant impact on morbidity at the farm level, this factor did make a difference in the health of individual calves (Tables VII and VIII). The differences in odds of being treated for scours for different methods of colostrum feeding, though only significant at $P \leqslant 0.11$, were consistent with those seen for pneumonia and crude morbidity. Calves that were assisted to suckle may have been weak calves to begin with, which could explain the higher odds of treatment in that group. The increased odds of treatment for calves given first colostrum by pail is unconditional for crude morbidity, but applies specifically to day-born calves for pneumonia. Perhaps night-born calves were more likely to have been suckled before morning when the farmer would initiate pail feeding. One explanation for the detrimental effect of pail feeding first colostrum is that newborn calves, struggling to learn how to drink from the pail, were not given sufficient time to take in adequate amounts of colostrum. The possibility of milk inhalation might also be increased under such circumstances. Fallon (1979) found no difference in amount of colostrum ingested or serum immunoglobulin levels in calves that were pail-fed colostrum versus those that were nipple-fed under experimental conditions. Thus, it is unlikely that the higher odds of morbidity in pail-fed calves can be attributed to the pail feeding per se.

Associations of morbidity with calf housing

The association of the use of outdoor calf hutches with significantly lower morbidity at both the farm and the individual calf level is consistent with results found under experimental conditions. The results in this study were not altered if calves housed indoors were divided into those which were kept in an air space separate from the adult cows and those kept in a contiguous air space. In previous experiments, hutch-reared calves either had fewer health problems (Erb and Murdock, 1951; Davis et al., 1954;

McNight, 1978) or experienced no health differences (Murley and Culvahouse 1954, 1958; Willett et al., 1968; Jorgensen et al., 1970) than calves reared in more conventional individual pens. It might be argued that, in this study, calves were simply treated less often in hutches, but that they suffered the same morbidity as other calves. If this were so, one might have expected to see higher mortality in hutch-reared calves. In fact, hutch housing was associated with lower mortality as well (Waltner-Toews et al., 1986c).

The effect of group penning of calves under field conditions is not clear, and the practice remains controversial (Roy, 1980b; Simensen, 1982). In this study, the direction of the effect of group penning on calf morbidity, relative to individual penning, was not consistent. The odds ratio was > 1 for crude morbidity and scours at the farm level, and for scours at the calf level, but negative for crude morbidity and pneumonia at the calf level. None of the effects were close to being statistically significant, so whatever the effect it appears to be minimal.

The shorter pneumonia treatments in pasture-born calves is consistent with the better two-week weight gains in the same calves. This, in combination with the calf housing results, indicate that calves born and raised outdoors were generally better off, healthwise, than calves born and raised in confinement.

Associations of morbidity with calf feeding practices

At the farm level, pail feeding of calves subsequent to the colostral period (as opposed to the use of nipple feeders of some sort) was associated with decreased odds of having above-median summer morbidity and winter pneumonia treatment days. It may be relevant that delayed introduction of pail feeding was associated with increased odds of having calves which harboured salmonellae, enteropathogenic *E. coli* and/or rota- and coronavirus (Waltner-Toews et al., 1986f). This, in turn, is hypothesized to relate to improper or inadequate disinfection of nipple feeders. However, under experimental conditions, no significant differences have been demonstrated in the disease rates in pail- and nipple-fed calves (Kesler et al., 1956; Wise and LaMaster, 1968; Morrill and Dayton, 1981). Although isolation of these organisms from calves on these farms was not significantly associated with morbidity (Waltner-Toews et al., 1986f), the circumstantial evidence is sufficiently compelling to suggest a rigorous study of the use of nipple feeders in young calves under common dairy farm conditions.

Farms where calves were fed waste milk (that is, from treated or mastitic cows) or milk replacer had significantly increased odds of having above-median summer morbidity (Table IV). A recent review of feeding waste milk to calves concluded that, with a few exceptions, no increased risk of disease in calves was associated with this practice (Kesler, 1981). The health effects of feeding milk replacer have been reported to be related to the quality of the replacer used, and the methods of preparation (Roy, 1980a). The negative effects seen in this study were significant only during the summer. This suggests that perhaps preparation practices of milk replacer and sanitation related to calf feeding were more problematic during the warm summer months.

Beneficial health effects of offering salt (winter scours) or fresh water (winter pneumonia) to calves have not been previously reported, but are biologically plausible. For instance, calves in the early stages of a disease would be able to take in salt and/or rehydrate themselves without having to wait for someone to take notice of them at the next feeding period. Recently, it was reported that ad libitum water intake in neonatal calves was associated with significantly increased calf starter intake and weight gains (Kertz et al., 1984). Although no differences in rates of scours were observed in that study between the two experimental groups of calves (one with ad libitum water available, and one with no water available), the effects on weight gains would certainly be consistent with a beneficial effect on the health of the calves. The detrimental effect of early teat removal on winter rates of calf scours treatments and of offering mineral supplements on pneumonia treatments are not open to any obvious biological interpretation and may represent chance associations, or may be surrogate measures for other factors not measured in this study.

ACKNOWLEDGEMENTS

This research was supported by the Ontario Ministry of Agriculture and Food through its Provincial Lottery Awards Program. Also, the senior author was a Fellow of the Medical Research Council of Canada while this research was undertaken, and gratefully acknowledges their support.

REFERENCES

Boyd, J.W., 1972. The relationship between serum immune globulin deficiency and disease in calves: a farm survey. Vet. Rec., 90: 645—649.

Bradley, J.A., Niild, L. and Dorward, W.J., 1979. Some observations on serum gammaglobulin concentrations in suckled beef calves. Can. Vet. J., 20: 227—232.

Breslow, N.E. and Day, N.E., 1980. Statistical Methods in Cancer Research. Vol. I. The Analysis of Case-Control Studies. International Agency for Research on Cancer, Lyons, France, 338 pp.

Davis, L.R., Autrey, K.M., Herlich, H. and Hawkins, G.E., 1954. Outdoor individual portable pens compared with conventional housing for raising dairy calves. J. Dairy Sci., 37: 562—570.

Dixon, W.J., (Editor), 1983. BMDP Statistical Software. University of California Press, Berkeley, 734 pp.

Draper, N.R. and Smith, H., 1981. Applied Regression Analysis, 2nd edn. John Wiley & Sons, Toronto, 709 pp.

Erb, R.E. and Murdock. F.R., 1951. Open shed versus conventional housing for dairy calves. J. Dairy Sci., 34: 503 (Abstr.).

Fallon, R.J., 1979. The effect of different methods of feeding colostrum on calf blood serum immunoglobulin levels. In: B. Hoffman, I.L. Mason, J. Schmidt, (Editors), Current Topics in Veterinary Medicine and Animal Science, Vol. 4. Calving Problems and Early Viability of the Calf. Martinus Nijhoff Publishers, Boston, pp. 507—521.

Hancock, D.D., 1983. Studies on the epidemiology of mortality and diarrheal morbidity in heifer calves in northeastern Ohio dairy herds. Ph.D. Thesis, Ohio State University, Wooster, OH.

Heider, L.E., 1980. Teat dip protects calves from navel ill. Hoard's Dairyman, Dec. 10 and 25, p. 1638.

Hoerlein, A.B. and Jones, D.L., 1977. Bovine immunoglobulins following induced parturition. J. Am. Vet. Med. Assoc., 170: 325—326.

House, J.A., 1978. Economic impact of rotavirus and other neonatal disease agents of animals. J. Am. Vet. Med. Assoc., 173: 573—576.

Hurvell, B. and Fey, H., 1970. Comparative studies of the gammaglobulin level in sera of market calves in relation to their health. Acta Vet. Scand., 11: 341—360.

Irwin, V.C.R., 1974. Incidence of disease in colostrum deprived calves. Vet. Rec., 94: 105—106.

Jorgensen, L.J., Jorgensen, N.A., Schingoethe, D.J. and Owens, M.J., 1970. Indoor versus outdoor calf rearing at three weaning ages. J. Dairy Sci., 53: 813—816.

Kertz, A.F., Reutzel, L.F. and Mahoney, J.H., 1984. Ad libitum water intake by neonatal calves and its relationship to calf starter intake, weight gain, feces score, and season. J. Dairy Sci., 67: 2964—2969.

Kesler, E.M., 1981. Feeding mastitic milk to calves: a review. J. Dairy Sci., 64: 719—723.

Kesler, E.M., McCarthy, R.D. and Knodt, C.B., 1956. Nipple versus pail feeding of milk to Holstein calves. J. Dairy Sci., 39: 542—546.

Lemeshow, S. and Hosmer, D.W., 1982. A review of goodness of fit statistics for use in the development of logistic regression models. Am. J. Epidemiol., 115: 92—106.

Mantel, N. and Haenszel, W., 1959. Statistical aspects of the analysis of data from retrospective studies of disease. J. Nat. Cancer Inst., 22: 719—748.

McNight, D.R., 1978. Performance of newborn dairy calves in hutch housing. Can. J. Anim. Sci., 58: 517—520.

Morrill, J.L. and Dayton, A.D., 1981. Method of feeding and access to fiber source for young calves. J. Dairy Sci., 64: 146—148.

Murley, W.R. and Culvahouse, E.W., 1954. The effect of management and housing upon growth and health of dairy calves. J. Dairy Sci., 37: 656 (Abstr.).

Murley, W.R. and Culvahouse, E.W., 1958. Open shed and portable pens versus conventional housing for young dairy calves. J. Dairy Sci., 41: 977—981.

Murphy, E.A., 1976. The Logic of Medicine. Johns Hopkins University Press, Baltimore, MD, 353 pp.

Roy, J.H.B., 1980a. Factors affecting susceptibility of calves to disease. J. Dairy Sci., 63: 650—664.

Roy, J.H.B., 1980b. The Calf, 4th edn. Butterworths, London, 442 pp.

SAS Institute Inc., 1982. SAS User's Guide: Basics, 1982 edn (94 pp.) and SAS User's Guide: Statistics, 1982 edn (584 pp.), SAS Institute Inc., Cary, NC.

Selman, I.E., 1973. The absorption of colostrum globulins by newborn calves. Ann. Rech. Veter., 4: 213—221.

Selman, I.E., De La Fuente, G.H., Fisher, E.W. and McEwan, A.D., 1971a. The serum immune globulin concentrations of newborn dairy heifer calves: a farm survey. Vet. Rec., 88: 460—464.

Selman, I.E., McEwan, A.D. and Fisher, E.W., 1971b. Studies on dairy calves allowed to suckle their dams at fixed times post partum. Res. Vet. Sci., 12: 1—6.

Simensen, E., 1982, 1983. An epidemiologic study of calf health and performance in Norwegian dairy herds. Acta. Agric. Scand., 32: 411—419, 421—427; 33: 57—64, 65—94.

Spooner, R.L., Halliday, R. and Williams, M.R., 1975. Genetics and disease in calves. In: J.M. Rutter (Editor), Perinatal ill-health in calves. Commission of the European Communities, Brussels, pp. 142—148.

Stott, G.H., Marx, D.B., Meneffe, B.E. and Nightengale, G.T., 1979. Colostral immunoglobulin transfer in calves. J. Dairy Sci., 62: 1632—1638, 1766—1773, 1902—1907, 1908—1913.

Susser, M., 1973. Causal thinking in the health sciences. Oxford University Press, New York, pp. 60—63.

Waltner-Toews, D., Martin, S.W., Meek, A.H., McMillan, I. and Crouch, C.F., 1985. A field trial to evaluate the efficacy of a combined rotavirus-coronavirus/*E. coli* vaccine in dairy cattle. Can. J. Comp. Med., 49: 1—9.

Waltner-Toews, D., Martin, S.W., Meek, A.H. and McMillan, I., 1986a. Dairy calf management, morbidity and mortality in Ontario Holstein herds. I. The data. Prev. Vet. Med., 4: 103—124.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986b. Dairy calf management, morbidity and mortality in Ontario Holstein herds. II. Age and seasonal patterns. Prev. Vet. Med., 4: 125—135.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986c. Dairy calf management, morbidity and mortality in Ontario Holstein herds. IV. Association of management with mortality. Prev. Vet. Med., 4: 159—172.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986d. Calf-related drug use on Holstein dairy farms in southwestern Ontario. Can. Vet. J., 27: 17—22.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986e. Selenium content in the hair of newborn dairy heifer calves and its association with pre-weaning morbidity and mortality. Can. J. Comp. Med., in press.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986f. An epidemiological study of selected calf pathogens on Holstein dairy farms in southwestern Ontario. Can. J. Comp. Med., in press.

Willeberg, P., Gerbola, M.A., Madsen, A., Mandrup, M., Nielsen, E.K., Riemann, H.P. and Aalund, O., 1978. A retrospective study of respiratory disease in a cohort of bacon pigs. Nord. Veterinaermed., 30: 513—525.

Willett, L.B., Abright, J.L., Cunningham, M.D. and Hinkle, C.N., 1968. Evaluation of three housing systems for raising dairy calves. J. Dairy Sci., 51: 971 (Abstr.).

Wise, G.H. and LaMaster, J.P., 1968. Responses of calves to open-pail and nipple-pail systems of milk feeding. J. Dairy Sci., 51: 452—456.